

# **Low Cost Very Large Diamond Turned Metal Mirror**

**Contract No. NNX10CB49C (SBIR 08-2 S2.04-9926) (MSFC)**

## **Mirror Technology SBIR/STTR Workshop**

**July 31 to August 2, 2012**

**Hyatt Regency, Rochester, NY.**

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# **Low Cost Very Large Diamond Turned Metal Mirror**

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## **OUTLINE**

- **CONCEPT AND GOALS**
- **MIRROR MFG. PROCESS**
- **PROGRESS TO DATE**
- **SUMMARY**

# Concept and Goals

- Develop and demonstrate a process for producing a light weight, stiff mirror substrate by electroplating a NiP alloy over a plastic foam mandrel which will be removed with solvent after plating.**
- Demonstration of diamond turning as a method of producing a high quality optical surface on the electroplated NiP substrate by producing a 300 mm (12 inch) diameter flat test mirror.**
- Optical inspection of the finished mirrors to evaluate mechanical stability and stiffness and the extent of mirror internal structure print through on the finished optical surface as a function of faceplate thickness.**
- Optical and dimensional inspection and characterization of the finished mirror for overall optical figure accuracy and surface smoothness achieved by diamond turning.**

# MIRROR MFG. PROCESS

Electroform tubes with the required length and diameter.

Machine plastic foam to desired shape of substrate master. With press-fit holes for tubes which go completely thru the foam master.

Install electroformed tubes in foam master so that the ends of the tubes are flush with the optical contour of the foam master.

Seal and coat plastic master with electrically conductive thin film to allow electroplating.

Electroplate the master and inserted tubes to completely encapsulate the assembly; joining the tubes to the front and back surfaces to form a stiff, continuous NiP structure.

Drill access holes through the NiP skin to allow introduction of solvent.

Use solvent such as acetone to dissolve the plastic master and leave only a mirror substrate of electroplated NiP alloy.

Diamond turn the exterior of the NiP mirror substrate to produce the desired optical contour and mounting and reference surfaces.

Optical inspection of the finished mirror.

# Weight of 1 Sq. Meter Mirror

**Polystyrene Foam Electroform Master**

**Backplate**  
0.040" Thk. x 50" dia.

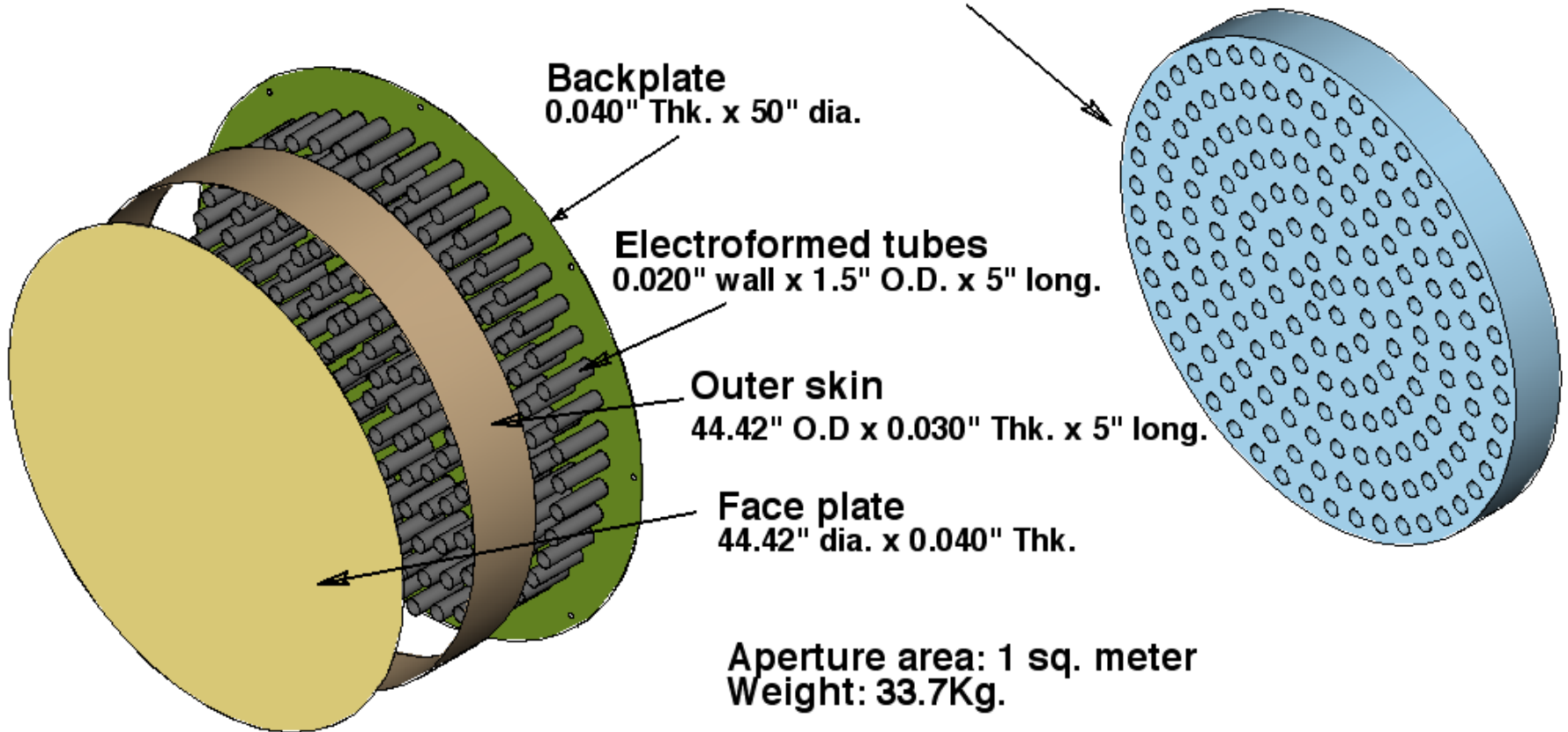
**Electroformed tubes**  
0.020" wall x 1.5" O.D. x 5" long.

**Outer skin**  
44.42" O.D x 0.030" Thk. x 5" long.

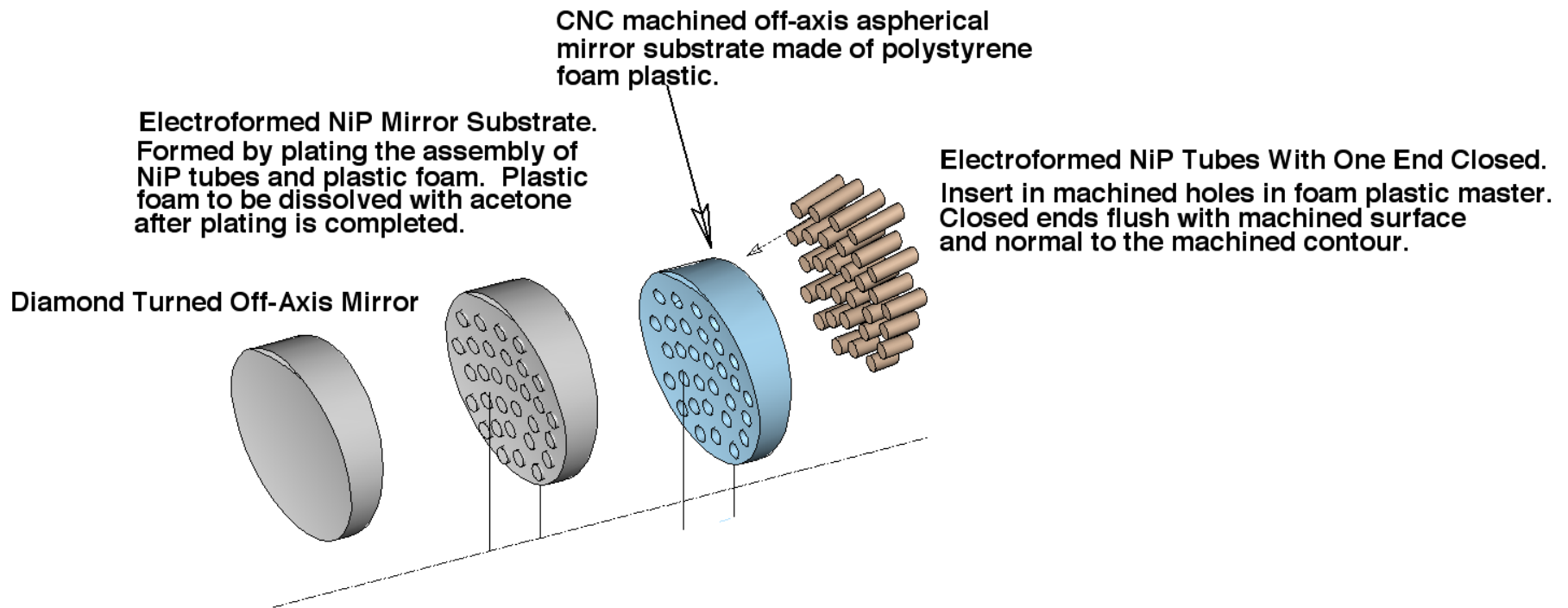
**Face plate**  
44.42" dia. x 0.040" Thk.

**Aperture area: 1 sq. meter**  
**Weight: 33.7Kg.**

**After diamond turning mirror surface and back plate.**  
**Weight: 27 Kg.**



# Off-Axis Aspheric Mirror



## 1.8 Meter Diameter Foam Plastic Mirror Substrate



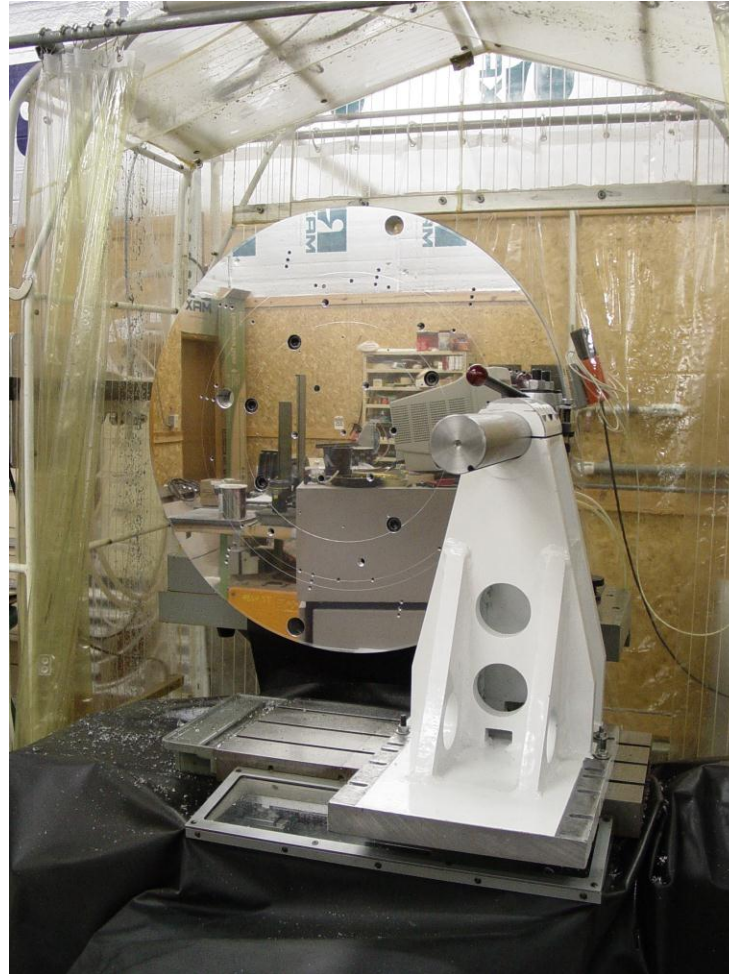


## 2.48 Meter Aluminum Mirror





# Large Part Diamond Turning Experience



# Technology

A very important enabling process for plating high phosphorus nickel alloys using an electrolytic process has been developed at the University of Alabama at Huntsville and at Marshall Space Flight Center. This plating process has been demonstrated to be capable of producing very low stress deposits of very high quality that allow excellent surfaces to be diamond turned on the NiP deposit. The electrolytic NiP plating process is not limited in plating thickness. Thick wall, structurally robust mirror substrates can be built up with this electroplating process.



## Electrodeposited Nickel Phosphorus



### Comparison of Nickel Phosphorus Deposition to Other Processes

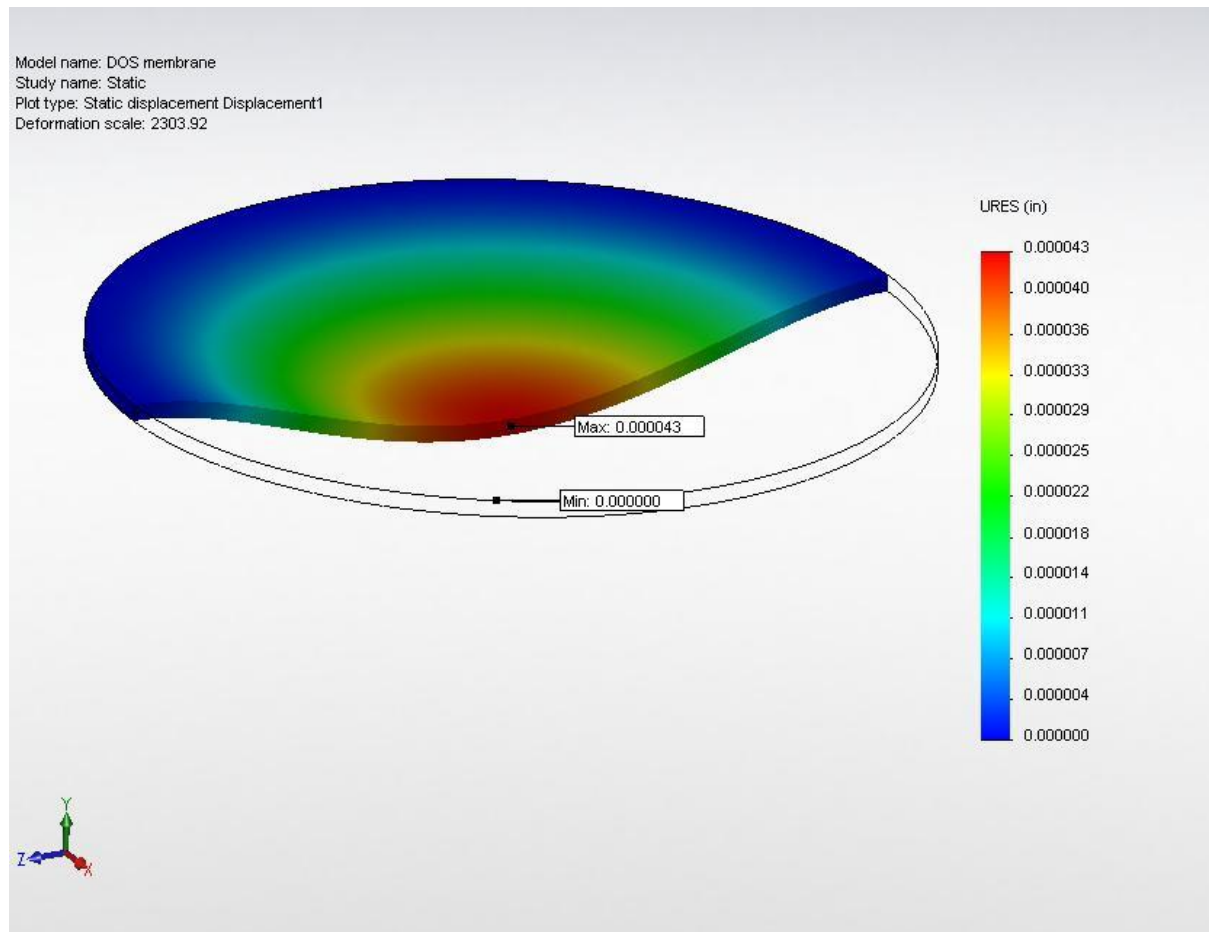
| Parameter                  | Nickel        | Electroless Nickel | NiP & NiCoP (Electrolytic) |
|----------------------------|---------------|--------------------|----------------------------|
|                            |               |                    |                            |
| Plating Temp °C            | 38 – 50       | 82 – 90            | 40 – 50                    |
| Control Method             | Soluble Anode | Chemical Replenish | Soluble Anode              |
| Yield (0.2%) (MPa)         | 500           | See UTS            | See UTS                    |
| MicroYield (MPa)           | 70            | 500 +              | 830 +                      |
| UTS Max (MPa)              | 800           | 850                | 1800 – 2150                |
| Specific Gravity           | 8.9           | 7.8 – 8.0          | 7.8 – 8.0                  |
| Stress Control (Real Time) | Yes           | No                 | Yes                        |
| Hardness (Rockwell C)      | 22 – 24       | 48 – 52            | 48 – 52                    |
| Diamond Machining          | No            | Yes                | Yes                        |
| Thick Deposits             | Yes           | No                 | Yes                        |

# Electroforming Technology Developed by UAH and MSFC for X-Ray Telescope Fabrication



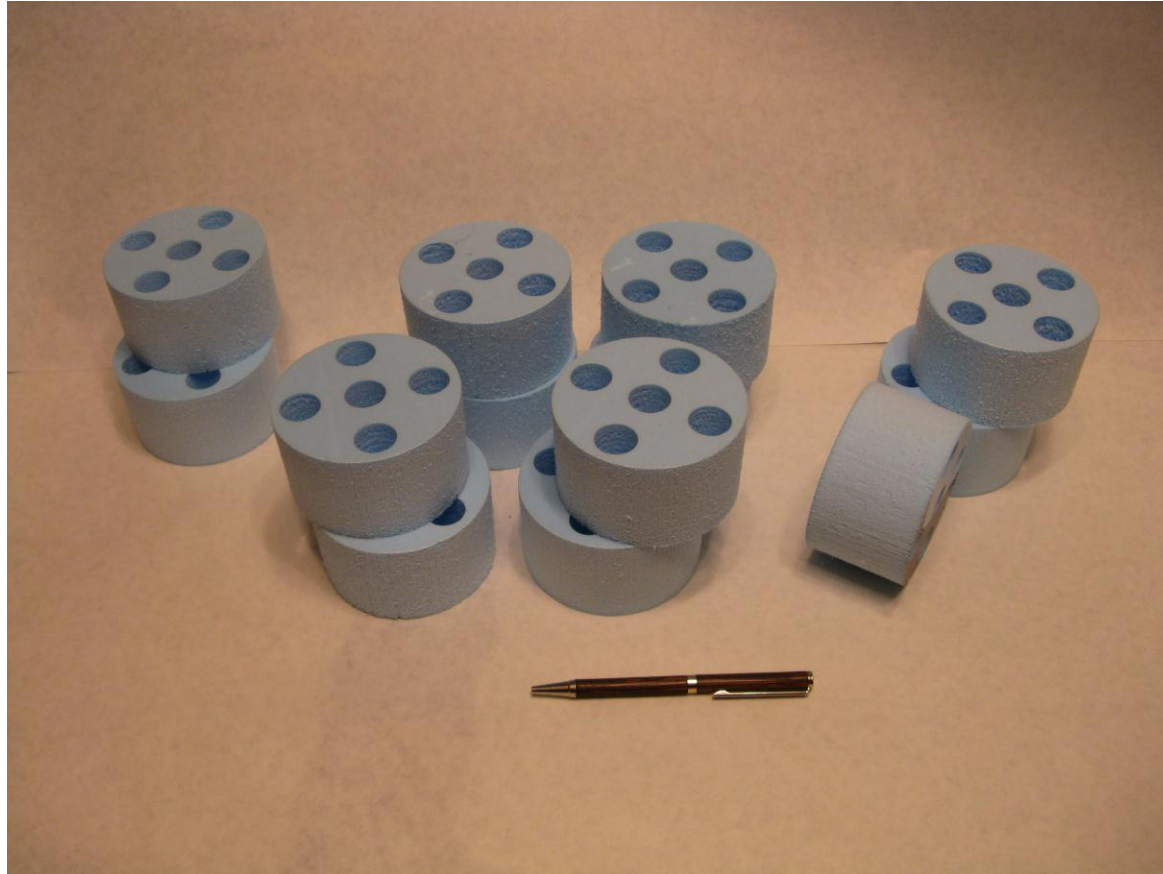
# Mirror Design

Plating thicknesses and diameter and spacing of tubes optimized for best performance.

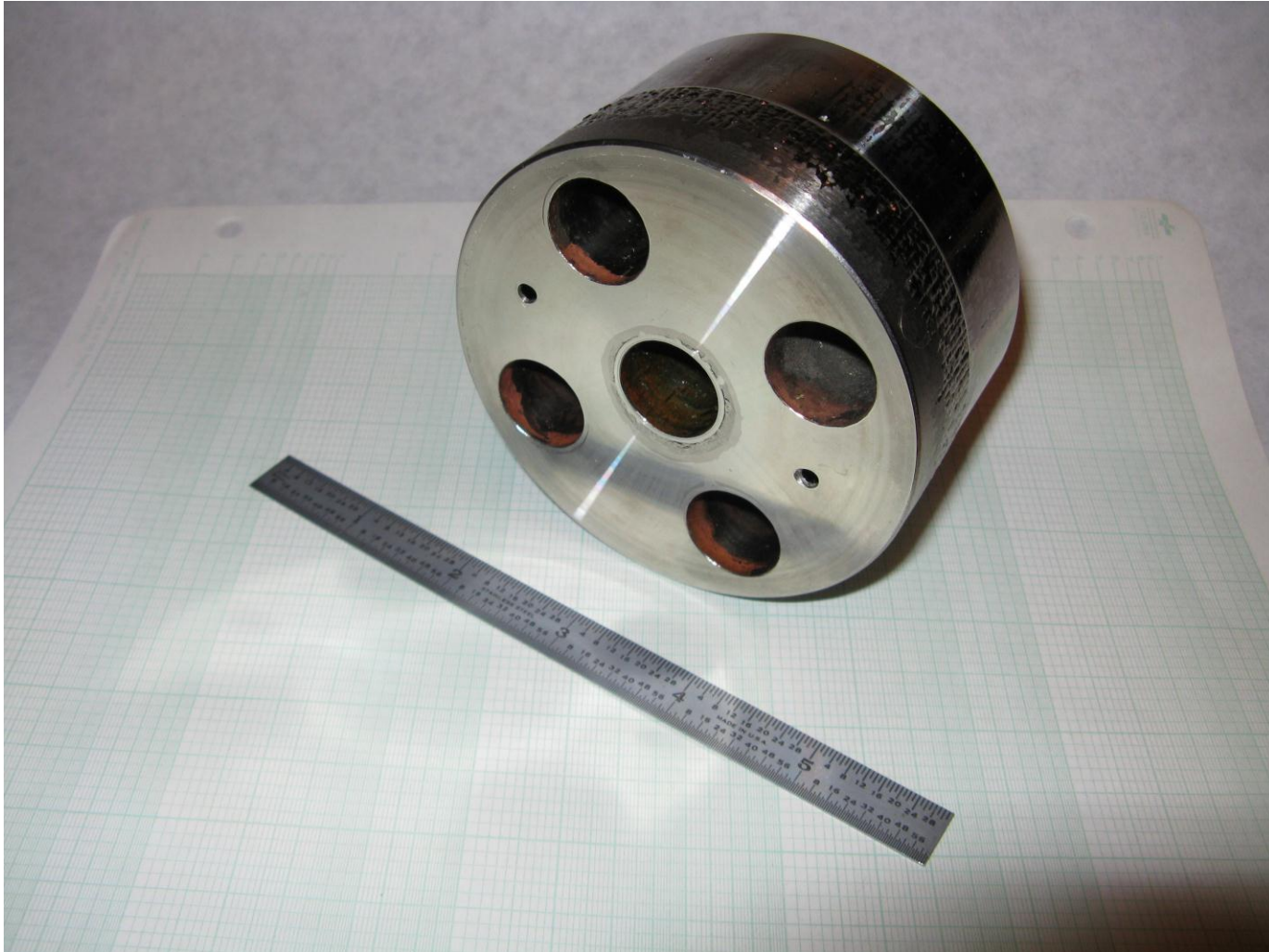




## 89mm Diameter Foam Master Forms



## Precision Machined Back of Plated Mirror Assembly



# Diamond Turned and Polished NiP Mirror



## **SBIR Goal Is A Low Cost Process For 3 Meter Mirrors**

- Large mirrors require production of thousands of tubes.
- Curved mirrors require tubes of different lengths.
- Large production of tubes of many lengths not cost effective.

### **PRODUCTION FRIENDLY METHOD FOR ELECTROFORMED TUBES**

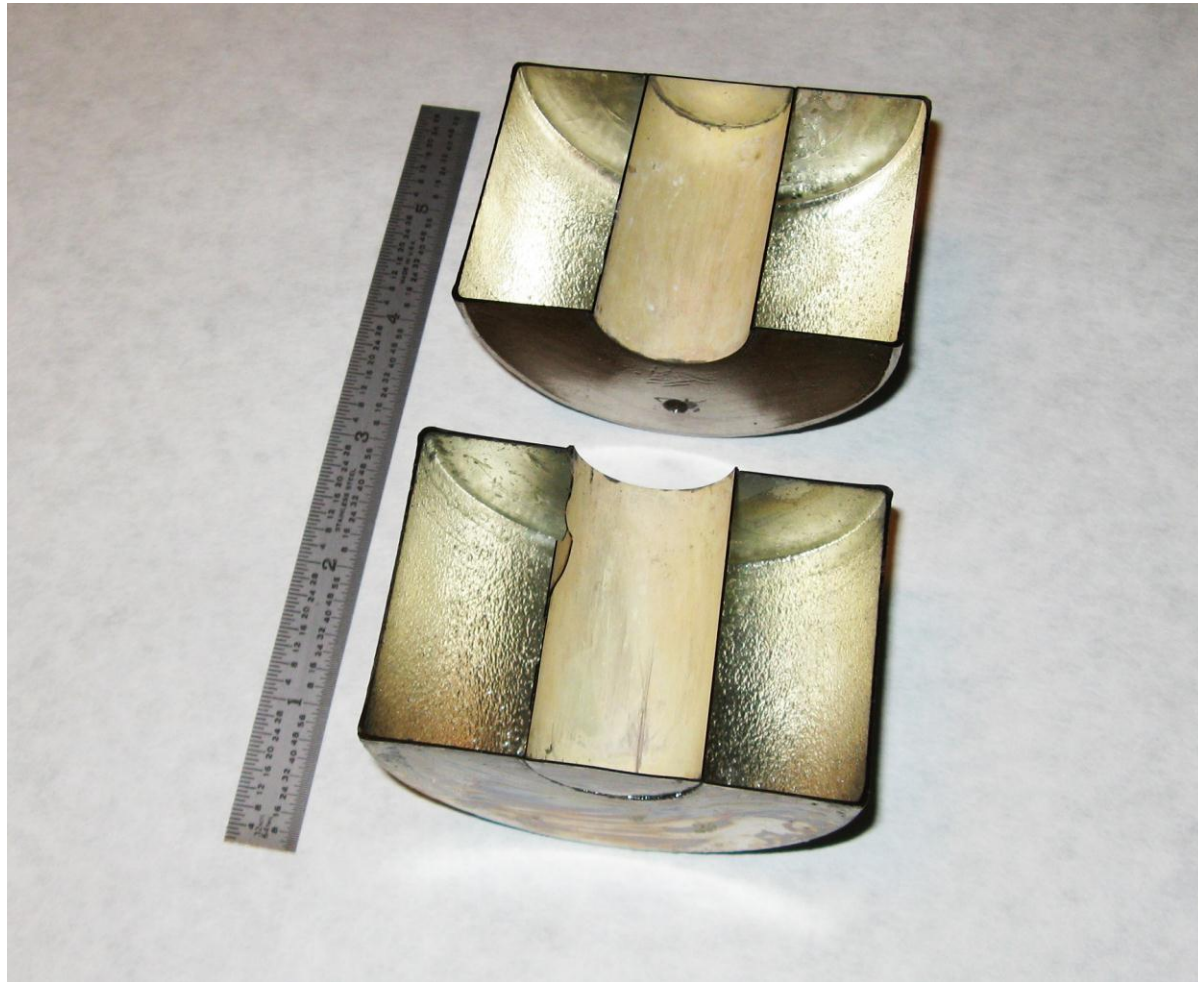
- Electroform long tubes and cut to required lengths.
- Open end tubes allow holes in foam to be parallel to optical axis.
- Inserted electroformed tube assemblies can be matched to contour.

# **Issues For Electroforming Tubes On Rods**

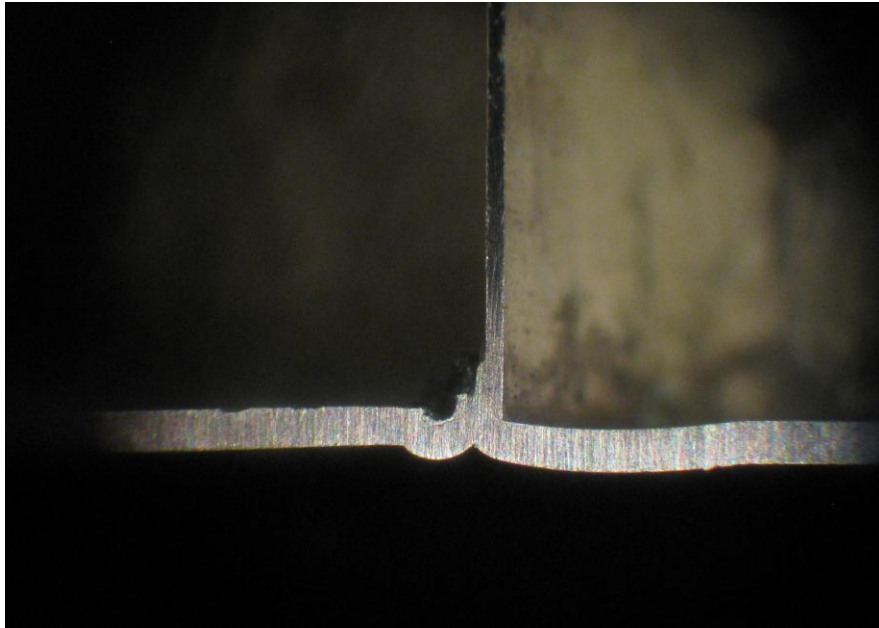
- **Cutting composite of hard nickel on soft rod is difficult.**
- **Mandrel rod must be smooth, round and constant diameter.**
- **Mandrel removal must be a reliable low force process.**
- **Obtaining a reliable strong and continuous bond of every tube to the encapsulation plating at both ends for all tubes is essential.**



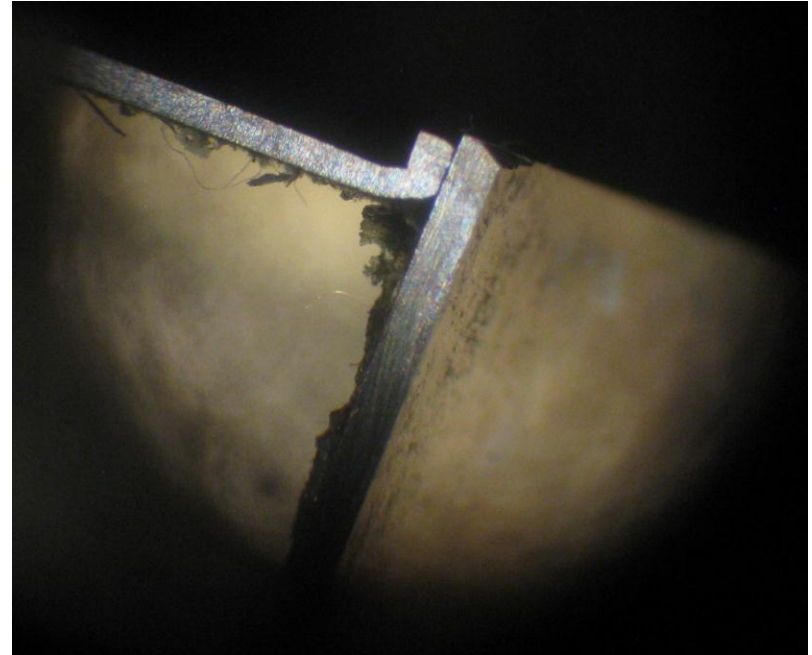
## Test Mirror Cut in Half for Evaluation of Joint Quality



## Micrographs of Unreliable Tube to Mirror Face Joint



**FRONT FACE**



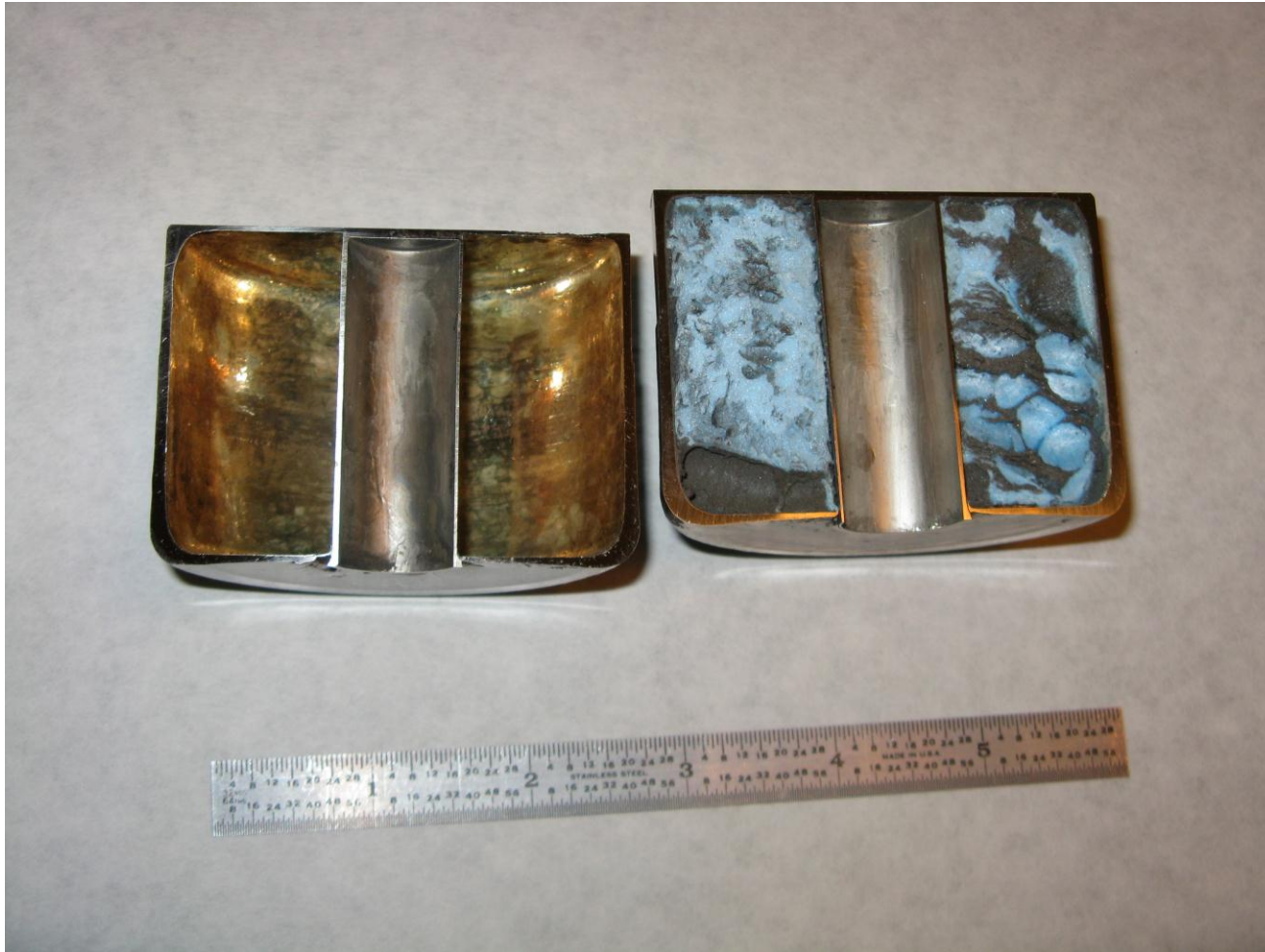
**BACK FACE**

## Four Test Mirror Substrates After NiP Plating





## Test Mirror Cut in Half for Evaluation of Joint Quality

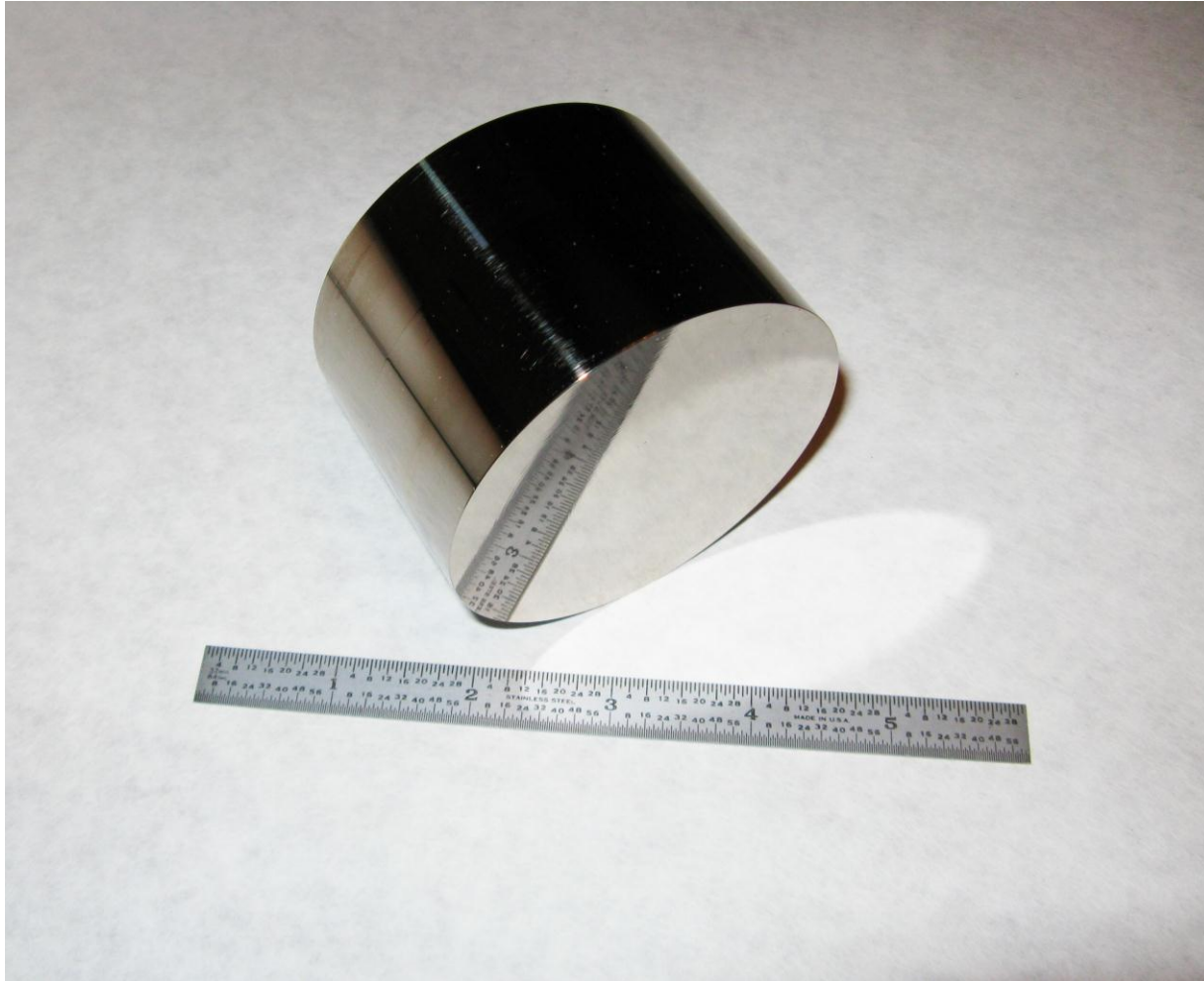


## High Quality NiP Plated Test Mirror Substrate





# Diamond Turned and Polished NiP Test Mirror



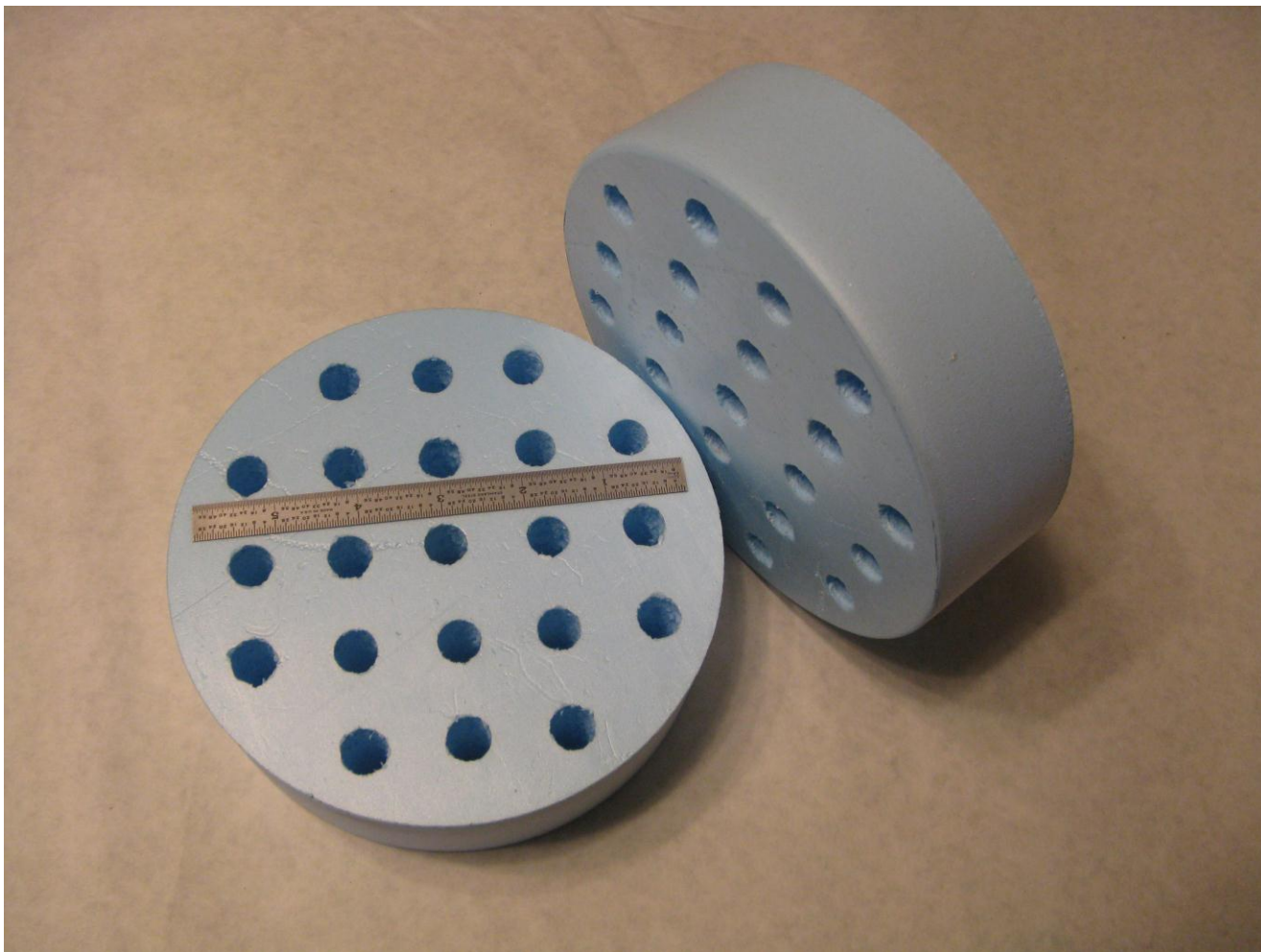
## **Mandrel Development**

- **Low cost composite mandrel material for electroplating of NiP.**
- **Easier faster cutting of plated rods to required length.**
- **Castable mandrel material is recycleable low cost and low waste.**
- **Composite tube mandrel allows mandrel removal by differential thermal expansion, melting and dissolution.**
- **New mandrel for electroplating meets SBIR goal of very low cost of large mirror substrates.**
- **Reliable composite tube mandrel material for mirror tests.**
- **A method of achieving a reliable bond of tubes to the encapsulating plating has been developed.**

# Sulfamate Ni Plated Composite Tube Assemblies

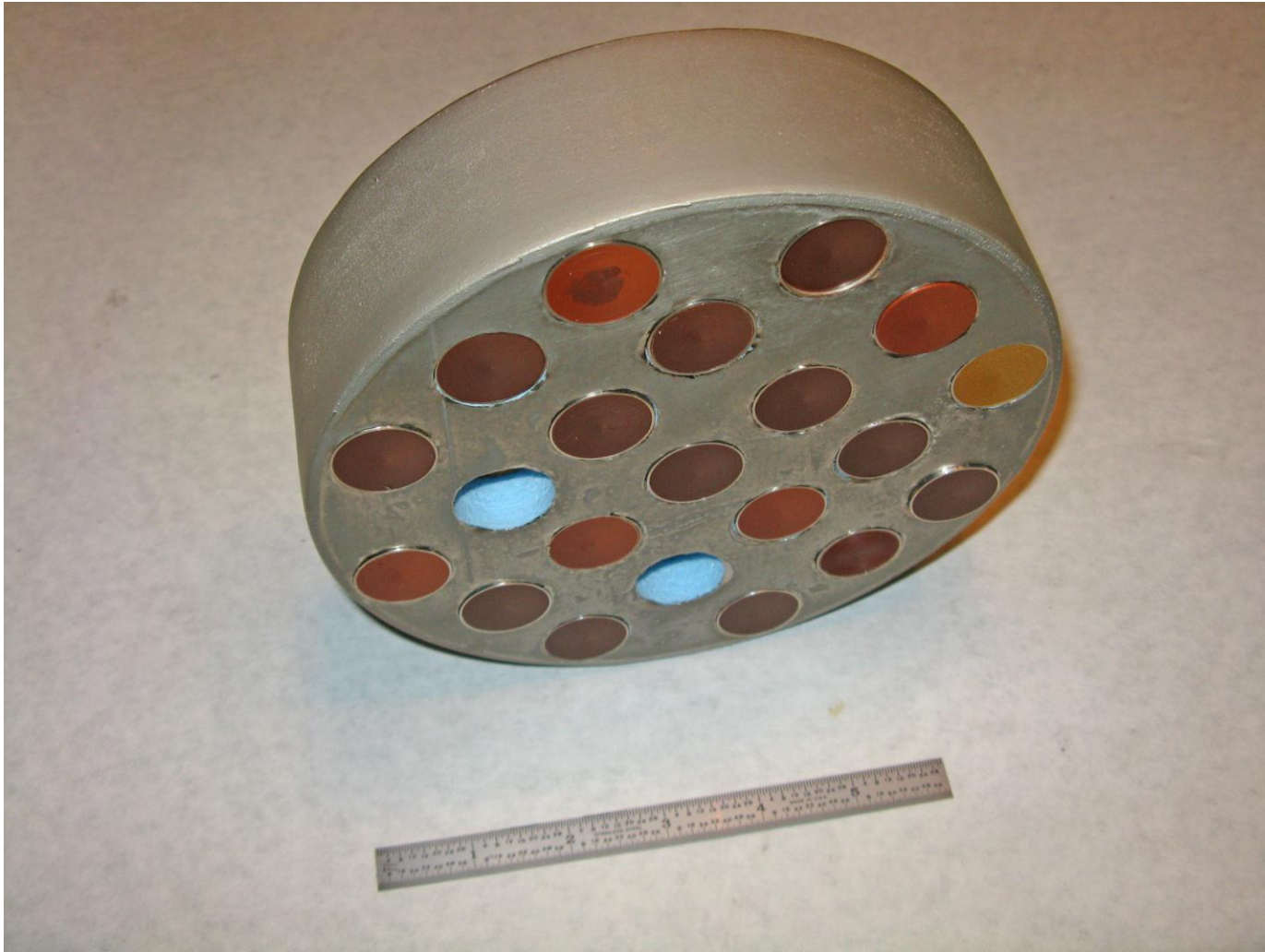


## 187 mm Diameter Polystyrene Foam Mandrels





## 187mm Diameter Mirror Assembly to be Plated with NiP





## 187mm Dia. Mirror Assembly In Fixture Ready to Plate



## 300 mm S-Ni Plated Mandrels Ready For Fitting with Tubes

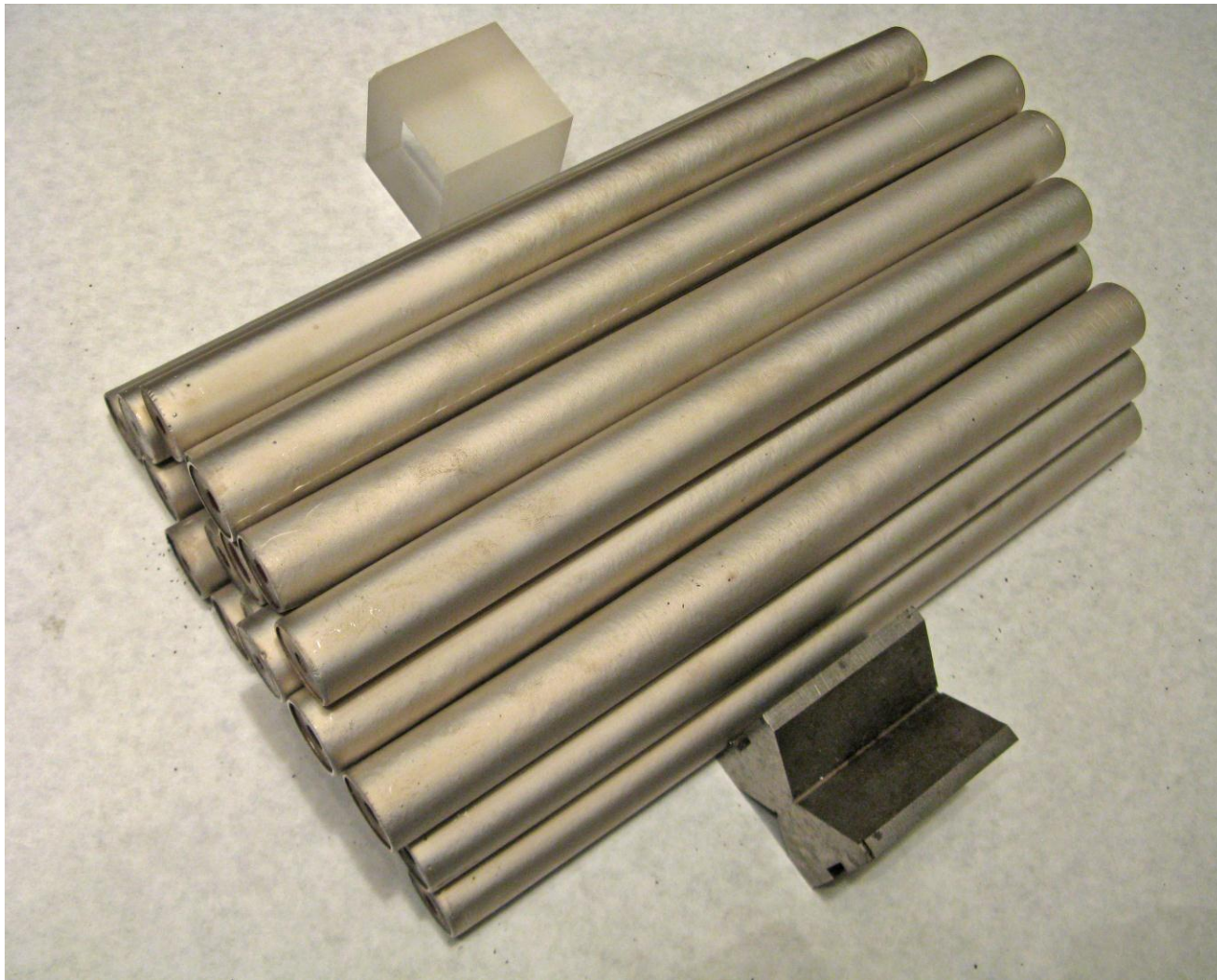




## Twenty-four Composite Rods Ready for Nickel Plating



## Twenty-Four S-Ni Plated Rods Ready to be Cut



# SUMMARY

- **Low Cost Mirror *SUBSTRATE* by Electroplating of NiP.**
- **Diamond Turning & Post Polish of NiP Electroformed Substrate.**
- **Low Cost Very Flexible Manf. Process for Large Mirrors.**
- **Low (10-30 Kg/Sq. Meter) Areal Density, Very stiff metal mirror.**
- **Only one material means low thermal distortion.**
- **Currently using composite tube mandrel which allows mandrel removal by thermal expansion, melting and dissolution.**
- **Plating of 187mm (7.375") mirror substrates will be followed by assembly and plating of 300 mm mirror substrates.**